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UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, D.C. 20230

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
The Portals
445 Twelfth Street, S.W.
Room TW-A325
Washington, DC 20554

Re: Revision of Part 15 of the Commission's Rules Regarding Ultrawideband Transmission Systems, ET Docket No. 98-153

Dear Ms. Salas:

Enclosed please find an original and 2 copies of the letter and accompanying reports from Assistant Secretary Gregory L. Rohde, National Telecommunications and Information Administration, Department of Commerce, to Chairman Kennard in the above-captioned proceeding. A copy of the letter and reports was also hand-delivered to Chairman Kennard, each of the Commissioners, and Bruce A. Franca, Acting Chief, Office of Engineering and Technology.

Please direct any questions you may have regarding this filing to the undersigned. Thank you for your cooperation.

Respectfully submitted,

Kathy Smith

Kathy Smith
Chief Counsel

Encloses

cc: The Honorable William E. Kennard
The Honorable Susan Ness
The Honorable Harold Furchtogott-Roth
The Honorable Michael Powell
The Honorable Gloria Tristani
Bruce A. Franca, Acting Chief, Office of Engineering and Technology

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NTIA SPECIAL PUBLICATION 01–43

ASSESSMENT OF COMPATIBILITY BETWEEN ULTRAWIDEBAND DEVICES AND SELECTED FEDERAL SYSTEMS

Special Publication

U.S. DEPARTMENT OF COMMERCE ● National Telecommunications and Information Administration

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ASSESSMENT OF COMPATIBILITY BETWEEN ULTRAWIDEBAND DEVICES AND SELECTED FEDERAL SYSTEMS

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EXECUTIVE SUMMARY

Introduction: Ultrawideband Devices

Recent advances in microcircuit and other technologies have allowed the use of very narrow pulses (typically less than a nanosecond) with very wide bandwidths in new applications in both radar and communication devices. These devices, called Ultrawideband (UWB) devices, may have instantaneous bandwidths of 25 percent or more of their center frequency. They are capable of locating nearby objects and can use processing technology to "see through walls" and communicate in multipath propagation environments, which makes them useful in many commercial and government applications. The developers of UWB devices, because of their low output power, low manufacturing cost, and anticipated wide marketability are seeking authorization from the National Telecommunications and Information Administration (NTIA) and the Federal Communications Commission (FCC) to operate UWB systems on an unlicensed basis.

UWB Devices As Unlicensed Devices

The existing rules for unlicensed devices were developed for devices using conventional narrowband technology and do not address UWB devices. Paragraph 15.209 of Volume 47 of the Code of Federal Regulations (47 CFR § 15.209) establishes the rules for the radiated emission limits of devices that can be authorized as unlicensed intentional radiators.[1] Intentional radiating unlicensed devices are not permitted to transmit signals in any of the 64 restricted bands, which occupy a total of 13.283 GHz of the spectrum between 90 kHz and 36.5 GHz, because of potentially harmful effects to critical radio services (47 CFR § 15.205) operating in them. Although UWB device output powers are often low enough to operate under these regulations, their bandwidths are so wide that most emit portions of their signal within the restricted bands. Moreover, operation of many proposed UWB devices under current Part 15 rules is made difficult because they seek to operate with much higher peak powers than the rules permit (47 CFR §15.35(b)). Revision of the current rules is required before UWB devices, as must be the case with any new system or technology, whether licensed or unlicensed, can be accommodated compatibly with existing systems in the electromagnetic environment.

The FCC and NTIA Programs

NTIA and the FCC must work closely with both the UWB community and the operators of conventional radiocommunication equipment they authorize and license to identify under what conditions UWB devices can operate without causing unacceptable interference to authorized and licensed radio services. To this end, the FCC initiated a formal proceeding that has included a *Notice of Inquiry* to gather information from the

[1] Even if unlicensed devices meet these limits, they are not allowed to cause interference and must accept interference from any station operating in accordance with the tables of frequency allocation (47 CFR §15.5 (c) & (d)).

interested parties on UWB devices and their potential impact on conventional devices and a *Notice of Proposed Rulemaking* to examine proposed rules for the regulation of UWB devices.[2]

NTIA, meanwhile, has conducted a series of measurements and analyses for characterizing and assessing the impact of UWB devices on selected Federal equipment operating between 400 and 6000 MHz, which includes 18 bands and a total of 2502.7 MHz of restricted spectrum.[3] The results include practical methods for characterizing UWB systems and providing the information needed to estimate or measure their potential to interfere with existing radio communications or sensing systems.[4]

NTIA calculated the maximum permissible, average Equivalent Isotropic Radiated Power (EIRP) density in a 1 MHz bandwidth (average EIRP, dBm/MHz (RMS)) that would allow a UWB device to transmit without exceeding the protection criterion determined for each of the systems analyzed after coordination with that system's users.[5] Throughout this report, the average power was calculated from the Root Mean Square (RMS) voltage of the UWB signal. For clarity and simplicity the average power has been written as average (RMS) power and the average spectral density expressed as dBm/MHz (RMS). In addition, NTIA calculated the minimum separation distance at which a UWB device with an average EIRP spectral density of -41.3 dBm/MHz (RMS), which is equivalent to the average field strength specified in Part 15 for devices operating above 1 GHz (a field strength of 500 μV/m at a 3 meter separation distance measured in a 1 MHz bandwidth), will ensure that the protection criteria are met in that receiver. Both the effects of one single UWB emitter on one receiver and of an aggregate of several UWB emitters on one receiver were analyzed. Throughout the assessment, the UWB devices analyzed were presumed to overlap the bands used by the equipment being assessed completely. The analytical results developed were been compared with the measurements made at NTIA's Institute for Telecommunication Sciences (ITS) in Boulder, Colorado and field measurements made at the Federal Aviation Administration facilities at Oklahoma City, Oklahoma.

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[2] See *Revision of Part 15 of the Commission's Rules regarding Ultra-Wideband Transmission Systems, ET Docket No. 98-153, Notice of Proposed Rulemakeing, 65 Fed. Reg. 37332 (June 14, 2000).*

[3] In addition, because of widespread concern, both the Interagency Government Executive Board, which oversees the development of the Global Positioning System (GPS), and the Federal Aviation Administration (FAA), have funded NTIA to conduct a related series of studies assessing UWB impact on GPS receivers. The measurements involving GPS receivers will be reported separately in a later document. See National Telecommunications and Information Administration, *Notice, Request for Comments on Global Positioning System/Ultrawideband Measurement Plan, 65 Fed. Reg. 49544 (Aug. 14, 2000).*

[4] NTIA and the Institute for Telecommunication Sciences with the support of the National Institute of Science and Technology verified the accuracy of the measurements made using readily available commercial test equipment in three separate ways. The first was by very accurately measuring the temporal (time domain) characteristics of the several devices and comparing the Fourier transformations of the signals in various bandwidths with measurements of the actual spectrums received in those bandwidths. The second was by theoretical analyses of the waveforms and their spectrums. The third way was through numerical simulations of the waveforms.

[5] The protection criteria, which are presented in Appendix A, are based on ITU-R Recommendations, ICAO Standards, and RTCA Minimum Operational Performance Criteria and were provided by the agencies operating the affected systems. NTIA's model is not generally accurate at ranges less than 200 meters due to uncertainties of near field, propagation and antenna gain.

The power levels of the UWB devices are expressed here as RMS spectral power densities, as noted above, rather than the average of the logarithms of the peak power densities measured with the video averaging technique used by the FCC for measuring narrow band Part 15 devices. Although NTIA recognizes that no single average detector function adequately describes the interference effects of UWB signals, the RMS detector function better represents the interference effects of UWB signals than averages of the logarithms of the peak detector output of the video filtered response used by the FCC for Part 15 measurements.

Results: Single Emitter

TABLES 1 and 2 provide the results of NTIA's analyses of the effect of single UWB emitters on selected devices. TABLE 1 shows the results for all the systems analyzed, assuming that receiver performance degradation is a function of the UWB signal average power, while TABLE 2 shows the results of the analyses for digitally modulated Earth stations in which receiver performance degradation may be a function of the UWB signal peak power. In TABLE 2 the lower PRF rows are shaded to reflect a possible restriction of the ratio of permissible peak power in a 50 MHz band to the RMS power in a 1 MHz band to less than 30 dB.[6]

To better understand TABLE 1 please look at the results for the Terminal Doppler Weather Radar (TDWR), which shows that a UWB device with an EIRP in the 5600-5650 MHz band of -41.3 dBm/MHz (RMS) could operate out-of-doors without exceeding the TDWR's protection criteria at heights of 2 meters or less with no geographic restriction. Moreover, a UWB device at 2 meters would require an in-band EIRP of -35 dBm/MHz (RMS) or greater to exceed the TDWR's protection criteria. The entry for the Air Route Surveillance Radar (ARSR-4), however, shows that a UWB device at a height of 2 meters with an EIRP of -41.3 dBm/MHz (RMS) in the 1240-1370 MHz band would have to stay about 6 km away to meet the radar's protection criterion or reduce its in-band EIRP to about -61 dBm/MHz (RMS). Please note also that TABLE 1 shows also that if UWB devices were to operate in the same horizontal plane as the TDWR or ARSR-4 antennas (see the columns labeled UWB Ht = 30 m), then the separation distance would have to increase to 6 km for the TDWR and over 15 km for the ARSR-4, or the in-band EIRPs would have to decrease to -63 dBm/MHz (RMS) for the TDWR and -82 dBm/MHz (RMS) for the ARSR-4.

[6] The 30 dB value was chosen for illustrative purposes and does not suggest an NTIA policy position. This 30 dB value would limit the PRF of UWB non-dithered devices to values greater than 3.5 MHz, and of UWB dithered devices to values greater than 12.5 MHz as shown in Appendix D.

NTIA validated both the aggregate interference assumptions and the methodology through two steps. First, from a limited number of measurements using UWB simulators, NTIA found that the received average (RMS) power from two identical UWB emitters is approximately twice that from a single UWB emitter, in agreement with the linear addition assumption. These results logically extend to an arbitrarily large number of UWB emitters. Second, NTIA examined four other aggregate interference methodologies described in the literature and found that all yielded results quite similar (within 2 dB) to those derived from the NTIA UWBRings model for a variety of hypothetical UWB scenarios. The UWBRings model, however, is unique in its ability to effectively consider various modes of radio propagation and three-dimensional receiver antenna patterns, both being key factors for aggregate studies.

Results of these studies show that received aggregate average (RMS) power from a uniform distribution of identical UWB emitters varies directly with the UWB EIRP, UWB emitter density, and number of active transmitters (transmitter activity factor). These results show that under ideal radio propagation conditions, *i.e.*, with no man-made or natural obstructions, aggregate interference levels from UWB devices can exceed that from a single emitter at densities as low as a few emitters per square kilometer or more than 1000 emitters per square kilometer, depending on the specific receiver.

While some studies of aggregate effects filed in response to the FCC's UWB NPRM used a comparable analytic methodology to that used by NTIA, the studies typically compared the aggregate interference levels to that from a single UWB emitter situated at an unrealistically close distance to the receiving antenna. As a result, conclusions form these studies are misleading.

NTIA also examined additional factors that tend to mitigate aggregate interference as an issue, including higher propagation losses associated with irregular terrain, urban and suburban environments, and building penetration, or antenna directivity. A possible methodology is described for applying these factors.

Interpretation of Results

This report shows that operation of UWB devices is feasible in portions of the spectrum between about 3.1 and 5.650 GHz at heights of about 2 meters with some operating constraints.[7] Operations of UWB devices below 3.1 GHz will be quite challenging and any policy developed will need to consider the results of the analyses of interactions of GPS and UWB systems underway at NTIA and other facilities.

While the study showed that aggregate UWB interference can be a significant factor to receiving systems under ideal propagation conditions, a number of mitigating factors

[7] UWB operations at greater heights between 3.1 and 5.650 GHz and near low elevation angle 4 GHz FSS earth stations may have to be constrained with respect to such factors as spectral output power, amount of operating time, and quantity of units operating in any area.

TABLE 2 shows that if the receiver performance degradation to digital Earth terminals is related to the peak power rather than the average power, separation distances or additional losses would have to increase to meet the protection criteria established for those receivers.

TABLE 2
Summary of Assessment of Effects of UWB Devices on Federal Systems For Peak Power Interactions with Digitally Modulated Systems[Note]

SYSTEM	Freq. (MHz)	UWB PRF (MHz)	UWB Height 2 Meters				UWB Height 30 Meters			
			Non-Dithered		Dithered		Non-Dithered		Dithered	
			Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria
Search & Rescue Sat. (SARSAT) Ground Station Land User Terminal (LUT)	1544-1545	0.001	-104	>15	-104	>15	-101	>15	-101	>15
		0.01	-94	12.0	-94	12.0	-91	>15	-91	>15
		0.1	-84	7.3	-84	7.3	-81	>15	-81	>15
		1	-74	4.2	-74	4.2	-71	11.3	-71	11.4
		>10	-69	3.1	-68	2.9	-66	6.1	-65	5.4
FSS Earth Station (20° Elevation)	3700-4200	0.001	-89	6.6	-89	6.6	-95	>15	-95	>15
		0.01	-79	3.9	-79	3.9	-85	>15	-85	>15
		0.1	-69	2.2	-69	2.2	-75	5.3	-75	5.3
		1	-59	1.2	-59	1.2	-65	1.7	-65	1.7
		10	-39	NA	-50	0.5	-45	0.25	-55	0.6
		100	-20	NA	-40	NA	-26	NA	-45	0.25
		500	-20	NA	-36	NA	-26	NA	-42	.20
FSS Earth Station (5° Elevation)	3700-4200	0.001	-104	12.3	-104	13.2	-130	>15	-130	>15
		0.01	-94	8.4	-94	8.4	-120	>15	-120	>15
		0.1	-84	5.1	-84	5.1	-110	>15	-110	>15
		1	-74	3.0	-74	3.0	-100	10.1	-100	10.2
		10	-54	1.0	-64	1.7	-80	1.3	-90	3.3
		100	-35	NA	-54	1.0	-61	0.44	-80	1.3
		500	-35	NA	-51	0.6	-61	0.44	-77	1.0

Note (1) The calculations were made at UWB PRF Values of, 0.001, 0.01, 0.1, 1, 10, 100, and 500 MHz. When the distance values and Maximum EIRP values were the same for a range, they were grouped together to save space in the table. Thus, for the LUT the calculations for 10, 100, and 500 MHz were the same and are shown in the row labeled >10 MHz. (2) The shaded areas are for PRF values that would result in peak-to-average power levels greater than 30 dB.

Results: Aggregate Emitters

NTIA examined the implications of possible aggregate interference from UWB devices and developed a number of findings, both general and specific. NTIA developed the UWBRings computer model for this study to calculate effectively aggregate interference levels in a given receiver under a variety of conditions. The model is based upon two fundamental assumptions – that the UWB emitters are uniformly distributed geographically and that the average power received from each emitter adds linearly.

must also be taken into account that may reduce or eliminate these aggregate affects. There are also numerous mitigating factors that could relax restrictions on operation of UWB devices below 3.1 GHz. Although these are discussed in the report, the development of suitable policy restrictions and guidance for both aggregate and single emitter interference is beyond the scope of this report and must await the results of the ongoing UWB measurement programs, including those of the GPS.

Schedule for Further Planned NTIA Studies

NTIA anticipates publishing a report of the measurement and assessment of the effects of UWB signals on GPS systems by the end of February 2001. NTIA will continue to work closely with industry, the FCC and Federal government agencies to ensure that interference will not occur.

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LIST OF ACRONYMS AND ABBREVIATIONS

AGL	Above Ground Level
APD	Amplitude Probability Distribution
ARSR	Air Route Surveillance Radar
ASR	Airport Surveillance Radar
ATCRBS	Air Traffic Control Radio Beacon System
BWCF	Bandwidth Correction Factor
CFAR	Constant False Alarm Rate
CFR	Code of Federal Regulations
C/I	Carrier-to-Interference Ratio
CISPR	International Special Committee for Radio Interference
COSPAS	Cosmicheskaya Systyema Poiska Avariynich Sudov
CW	Continuous Wave
dB	Decibel
dBi	Decibels Referenced to an Isotropic Antenna
dBm	Decibel Referenced to a Milliwatt
dBW	Decibels Referenced to a Watt
DME	Distance Measuring Equipment
DCF	Detector Correction Factor
DoD	Department of Defense
EIRP	Equivalent Isotropic Radiated Power
EMC	Electromagnetic Compatibility
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FM	Frequency Modulation
FMCW	Frequency Modulated Continuous Wave
FSS	Fixed Satellite Service
GF	Gating Factor
GHz	Gigahertz (10^9 Hertz)
GMF	Government Master File
GPR	Ground Penetrating Radar
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
IF	Intermediate Frequency
I_{MAX}	Maximum Permissible Average or Peak Interference Level, in dBm
I/N	Interference-to-noise Ratio
I+N	Interference plus Noise
ITM	Irregular Terrain Model
ITS	Institute for Telecommunication Sciences
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union Radiocommunication Sector
kHz	Kilohertz (10^3 Hertz)
km	Kilometer